



DEPARTMENT OF THE NAVY
NAVAL UNDERSEA WARFARE CENTER
DIVISION NEWPORT
OFFICE OF COUNSEL (PATENTS)
1176 HOWELL STREET
BUILDING 112T, CODE 000C
NEWPORT, RHODE ISLAND 02841-1708

PHONE: 401 832-4736
DSN: 432-4736

FAX: 401 832-1231
DSN: 432-1231



Attorney Docket No. 82831
Date: 28 December 2005

The below identified patent application is available for licensing. Requests for information should be addressed to:

PATENT COUNSEL
NAVAL UNDERSEA WARFARE CENTER
1176 HOWELL ST.
CODE 000C, BLDG. 112T
NEWPORT, RI 02841

Serial Number 10/956,527

Filing Date 29 September 2005

Inventor Donald H. Steinbrecher

If you have any questions please contact James M. Kasischke, Supervisory Patent Counsel, at 401-832-4230.

MULTI-PURPOSE ELECTROMAGNETIC RADIATION
INTERFACE SYSTEM AND METHOD

TO WHOM IT MAY CONCERN:

BE IT KNOWN THAT DONALD H. STEINBRECHER, citizen of the United States of America, employee of the United States Government and resident of Brookline, County of Norfolk, Commonwealth of Massachusetts, has invented certain new and useful improvements entitled as set forth above of which the following is a specification:

MARK HOMER, ESQ.
Reg. No. 41848
Naval Undersea Warfare Center
Division Newport
Newport, RI 02841-1708
TEL: 401-832-6679
FAX: 401-832-1231

1 Attorney Docket No. 82831

2
3 MULTI-PURPOSE ELECTROMAGNETIC RADIATION

4 INTERFACE SYSTEM AND METHOD

5
6 STATEMENT OF GOVERNMENT INTEREST

7 The invention described herein may be manufactured and used
8 by or for the Government of the United States of America for
9 governmental purposes without the payment of any royalties
10 thereon or therefore.

11
12 CROSS-REFERENCE TO RELATED APPLICATIONS

13 This patent application is related to co-pending U.S. Patent
14 Application entitled ELECTROMAGNETIC RADIATION INTERFACE SYSTEM
15 AND METHOD (Navy Case No. 82744) having same filing date, which
16 is hereby incorporated by reference in its entirety.

17
18 BACKGROUND OF THE INVENTION

19 (1) Field of the Invention

20 The present invention relates generally to systems for
21 controlling electromagnetic radiation, and more particularly to
22 an electromagnetic wave interface that may be utilized to capture
23 electromagnetic radiation such as radio waves and transform the
24 radiation by some desired means such as by absorbing the

1 radiation completely for stealth purposes, reflecting the
2 radiation with desired characteristics that alter the radiation
3 in a desired manner, by transforming the radiation into digital
4 data without analog receivers, and/or otherwise processing the
5 radiation.

6 (2) Description of the Prior Art

7 Traditional antenna theory requires that as the capture area
8 of an antenna becomes smaller, the Q increases, and the bandwidth
9 narrows. Thus, according to traditional antenna theory it is
10 impossible to provide a wide bandwidth antenna with a small
11 capture area. Moreover, prior art broadband receiving systems
12 are performance limited by the inability to realize sufficient
13 spurious-free dynamic range (SFDR) in the analog portions of the
14 receiving systems. Prior art broadband receiving systems may
15 often be limited to about 60 db SFDR.

16 Prior art antennas are also limited as to the type of
17 functions that are available. Generally, prior art antennas are
18 dedicated to perform a certain function and are not suitable for
19 other specific functions. For instance, a prior art antenna
20 design may be utilized as a transceiver. However, a prior
21 antenna design will not be useable for transceiver operation,
22 and/or stealth operation as being electrically "black," and/or
23 altering radio wave electromagnetic radiation Doppler effects to
24 produce a desired reflection which may indicate a body traveling

1 at a different speed than it is, and/or for producing a radio
2 reflection signature that may be different from the actual body
3 producing the reflection.

4 The following U.S. Patents describe various prior art
5 systems that act in some way on electromagnetic radiation. Many
6 of the disclosed structures are not broadband structures and
7 several are limited to certain frequencies, such as sunlight, or
8 other very specific functions not related to radio waveband
9 electromagnetic radiation.

10 U.S. Patent No. 3,836,967, issued September 17, 1974, to R.
11 W. Wright, discloses a structure for impeding the reflection of a
12 beam of electromagnetic waves from the surface of an object and
13 more particularly to a flexible, thin-wall structure which is
14 suitable as a broadband absorber of microwave energy.

15 U.S. Patent No. 4,582,111, issued April 15, 1986, to R. D.
16 Kuehn, discloses a substantially radiation absorbing layer of
17 metal having a microstructured surface characterized by a
18 plurality of randomly positioned discrete protuberances of
19 varying heights and shapes, which protuberances have a height of
20 not less than 20 nanometers nor more than 1500 nm, and the bases
21 of which contact the bases of substantially all adjacent
22 protuberances. The metal layer, which may be a coating on a
23 variety of substrates, is useful as a radiation absorber

1 (particularly solar). A method is disclosed for producing such
2 layers.

3 U.S. Patent No. 4,672,648, issued June 9, 1987, to Mattson
4 et al., discloses an off-focal radiation collimator which
5 includes a plurality of radiation absorbing elements supported in
6 spaced relationship with respect to one another in a housing such
7 that each element is aligned along radii extending from the focal
8 spot of a radiation source. The off-focal collimator is
9 preferably disposed between the radiation source and a primary
10 beam collimator. The off-focal collimator also acts as a
11 radiation beam compensator. By varying the spatial density of
12 the radiation absorbing elements by a function of location within
13 the housing, the radiation beam can be shaped to any desired
14 profile.

15 U.S. Patent No. 4,942,402, issued July 17, 1990, to Prewer
16 et al., discloses an absorber for radiation of frequency of the
17 order of 1 THz is formed of a body of cured silicone-based
18 elastomer containing an inert, powdered siliceous filler. Both
19 the elastomer and the filler are electrically insulating and the
20 surface of the absorber that is exposed to the radiation is
21 preferably profiled to enhance absorption of the radiation. The
22 profiling preferably takes the form of an array of sharp-pointed
23 pyramids having rectangular or triangular bases. A method of
24 molding such absorbers is also disclosed.

1 U.S. Patent No. 5,565,822, issued October 15, 1996, to
2 Gassmann et al., discloses a TEM waveguide arrangement such as
3 are used in testing the electromagnetic compatibility of
4 electronic devices in electromagnetic fields wherein a plate-
5 shaped inner conductor is connected via electrically parallel-
6 connected tubular resistors to an electrically conductive,
7 spherical rear wall. This rear wall is electrically connected to
8 an outer conductor and grounded. Radio-frequency absorbers are
9 mounted on the rear wall for the purpose of absorbing TEM waves,
10 the RF short-point absorbers adjacent to the tubular resistor
11 being smaller than the remaining RF long-point absorbers, in
12 order to reduce the capacitive influence of the tubular
13 resistors. Identical tubular resistors are arranged perpendicular
14 to the plane of the drawing of FIG. 1 in accordance with a
15 current density distribution in such a way that they are more
16 closely adjacent at the edge than in the middle of the inner
17 conductor.

18 U.S. Patent No. 5,710,564, issued January 20, 1998, to Nimtz
19 et al., discloses an electromagnetic wave measurement chamber
20 wherein the sidewalls and the ceiling of the chamber are lined
21 with contiguous pyramids. The pyramid vertices point into the
22 chamber. The structure element has a frame formed by bars made of
23 an electrically insulating glass fiber material and an outer
24 skin. The outer skin is cut out of a surface resistance material

1 web. The surface resistance material web is produced by
2 continuously or almost continuously coating a mechanically
3 flexible support web with an electroconductive layer made of a
4 metallic material.

5 U.S. Patent No. 6,295,032 B1, issued September 25, 2001, to
6 A. S. Podgorski, discloses electromagnetic radiating structures
7 suitable for use as antennas or in electromagnetic field test
8 facilities. An electromagnetic field test facility is a test
9 enclosure used for observing the behavior of equipment in the
10 presence of strong electromagnetic fields and for detecting
11 radiation from the equipment. A broadband Gigahertz field
12 electromagnetic test facility is also disclosed in which an array
13 of horn antennas is used to illuminate a relatively large test
14 area at high power densities, or to measure radiation from tested
15 equipment in a frequency range extending from DC to hundreds of
16 Gigahertz.

17 U.S. Patent Application Publication No. 2001/0003444 A1,
18 published June 14, 2001, to Mangenot et al., discloses a
19 radiating source for transmitting and receiving, intended to be
20 installed on board a satellite to define a radiation pattern in a
21 terrestrial zone. The source is intended to be disposed in or
22 near the focal plane of a reflector associated with other sources
23 corresponding to other terrestrial zones. The source includes a
24 plurality of radiating apertures, each of which has an efficiency

1 at least equal to 70%, and feed means for feeding said radiating
2 apertures. The radiating apertures and their feed means are such
3 that the energy radiated by all of the radiating apertures is
4 practically limited to the corresponding reflector, at least for
5 transmission.

6 U.S. Patent Application Publication No. 2001/0033377 A1,
7 published October 25, 2001, to Welch et al., discloses systems
8 for, and methods of controlling radial energy density profiles
9 in, and/or cross-section dimensioning of electromagnetic beams in
10 polarimeters, ellipsometers, reflectometers and
11 spectrophotometers.

12 U.S. Patent Application Publication No. 2001/033207 A1,
13 published October 25, 2001, to Anderson et al., discloses phase
14 shifting plasma electromagnetic waveguides and plasma
15 electromagnetic coaxial waveguides, as well as plasma waveguide
16 horn antennas, each of which can be reconfigurable, durable,
17 stealth, and flexible are disclosed. Optionally, an energy
18 modifying medium to reconfigure the waveguide such that
19 electromagnetic waves of various wavelengths or speeds can be
20 propagated directionally along the path can be used. Similarly,
21 these waveguides may be modified into coaxial configurations.

22 U.S. Patent No. 6,300,918 B1, issued October 9, 2001, to
23 Riddle et al., discloses a phased array antenna that includes a
24 plurality of multiple spiral arm antenna elements. The antenna

1 elements are hexagonal in shape and are aligned in a triangular
2 lattice geometry, where the elements are arranged in rings around
3 a common center element. The elements include at least two arms
4 which terminate at opposite sides of the element. The ends of the
5 arms of diagonally adjacent elements are positioned proximate to
6 each other to provide inter-element coupling to increase the
7 bandwidth of the antenna. The tight coupling of the antenna
8 elements also reduces the RCS of the antenna.

9 U.S. Patent No. 6,215,448 B1, issued April 10, 2001, to
10 DaSilva et al., discloses a selected length of antenna for a
11 device under test which is placed within a conductive inner
12 cylinder, forming an unterminated "input" coaxial transmission
13 line. The inner cylinder is in turn within and coaxial with a
14 conductive outer cylinder, forming an "output" transmission line.
15 The inner cylinder is the center conductor of the output
16 transmission line, and in a region extending beyond the extent of
17 the antenna therein, conically tapers to being a normal center
18 conductor of solid cross section. The outer cylinder matches this
19 taper to maintain a constant characteristic impedance Z_0 say, 50
20 ohms, for the output transmission line, which then delivers its
21 output signal to a matched terminating load in measurement
22 equipment via either a coaxial connector or an interconnecting
23 length of auxiliary transmission line. These triaxially nested
24 input and output transmission lines are supported at a driven end

1 by an RF tight box that contains a mounting fixture to support
2 the device under test in a fixed and appropriate relation to the
3 triaxially nested input and output transmission lines, and that
4 is lined with anechoic RF absorbing material.

5 U.S. Patent No. 6,021,241, issued February 1, 2000, to
6 Bilbro et al., discloses an array of optical fiber bundles
7 includes one or more diffractive elements positioned above gaps
8 between adjacent bundles. Incident radiation produces
9 mathematically determinative diffraction patterns on the
10 respective input faces of the adjacent bundles. Radiation
11 intensity values for areas between and along the abutting edges
12 of adjacent optical fiber bundles can be determined using the
13 diffraction patterns. These intensity values can be assigned to
14 other pixels so that precise, seamless images can be
15 reconstructed.

16 U.S. Patent No. 6,285,495 B1, issued September 4, 2001, to
17 Baranov et al., discloses an optical element comprising a
18 plurality of transparent layers comprising one or more passive
19 layers and one or more active layers wherein said passive layers
20 facilitate the transmission of electromagnetic radiation in a
21 substantially unaltered form and the at least one active layers
22 include an active material dispersed through the active layer and
23 having the capacity to intercept electromagnetic radiation of at
24 least one predetermined wavelength or range of wavelengths and

1 redirect at least a portion of energy of the intercepted
2 radiation into the interior of the optical element, said layers
3 being in face to face relationship and being optically coupled to
4 each other.

5 U.S. Patent No. 6,329,955 B1, issued December 11, 2001, to
6 McLean et al., discloses a broadband antenna incorporating both
7 electric and magnetic dipole radiators includes a tapered feed,
8 such as a bow-tie feed, having a central feed point and first and
9 second outer regions displaced from the central feed point. One
10 or more conducting loop elements are connected between the outer
11 regions of the tapered feed. Top loading capacitive elements
12 extending from each of the outer regions may also be provided.

13 U.S. Patent No. 6,297,774 B1, issued October 2, 2001, to H.
14 H. Chung, discloses a high performance phased array antenna
15 system for receiving satellite communication signals, with a
16 structural top layer formed as a perforated plate (or solid plate
17 made of very low loss plastic material), a middle layer
18 functioning as the single layer antenna aperture layer,
19 preferably in the form of a single layer printed circuit board on
20 which is formed an array of antenna elements and plurality of
21 stripline feed network circuits, each combining in-phase outputs
22 from several adjacent antenna elements, the bottom layer
23 functioning as the ground plane for the antenna aperture layer
24 and also including a single level waveguide combining network for

1 combining in-phase outputs from stripline feed network circuits
2 electromagnetically coupled to respective transition probe holes
3 of the waveguide combining network. Each antenna element is
4 preferably a dual polarization octagonal patch antenna element
5 disposed on a common surface of the antenna aperture layer. Each
6 feed network circuit is preferably in a form of an air-stripline
7 feed network separated by a layer of air dielectric from the
8 ground plane and preferably is on the same surface of the antenna
9 aperture layer as the antenna elements. The single level
10 waveguide combining network is preferably an integral structure
11 including dual orthogonal polarization waveguide sections and
12 dual orthogonal polarization ports. The dual orthogonal
13 polarization waveguide sections lay in the same plane and
14 preferably are asymmetrically disposed on either side of a common
15 wall, with each containing a branched cavity symmetrically
16 disposed about a respective centerline.

17 U.S. Patent No. 6,292,140 B1, issued September 18, 2001, to
18 D. P. Osterman, discloses a novel antenna which is useful in the
19 manufacture of a bolometer integrated on a silicon chip. An
20 opening in the silicon chip is spanned by two separate thermally,
21 isolated structures. A thin-film antenna, comprising two parts,
22 is located on the structures, with one antenna part on each
23 structure. Radiation received in the larger of the two antenna
24 parts is coupled electromagnetically into the smaller part, where

1 it causes a current to flow. The current is dissipated as heat. A
2 thin-film thermometer measures the temperature rise of the
3 smaller antenna part, due to the dissipated heat. The bolometer
4 achieves improved performance in comparison to previous bolometer
5 designs because the radiation is dissipated in a part of the
6 antenna only, and the bolometer is free from impedance-matching
7 constraints of other designs.

8 U.S. Patent No. 5,926,147, issued July 20, 1999, Sehm et
9 al., discloses an antenna design that includes a plurality of
10 radiating elements which radiate electro-magnetic energy, and
11 feeders which feed the electromagnetic energy to the radiating
12 elements. The feeders have a supply network substantially at the
13 same level in the antenna thickness direction. In order to
14 achieve a small antenna with adequate properties for radio link
15 usage, the radiating elements are arranged next to the supply
16 network in the thickness direction and include box horn antennas
17 which have a step, characteristic of a box horn, in the plane of
18 the magnetic field.

19 U.S. Patent No. 5,539,421, issued July 23, 1996, to S. Hong,
20 discloses a planar antenna, for use in satellite communication
21 that is intended to provide higher aperture efficiency, improved
22 circular polarization and increased production tolerability. The
23 antenna comprises a waveguide and an array of $M \times N$ helical antenna
24 elements, wherein M and N are integers. The waveguide includes a

1 primary feeder waveguide and a set of M secondary feeding
2 waveguides, wherein each of the M secondary feeding waveguides is
3 provided with N helical antenna elements, each of the secondary
4 feeding waveguides is coupled to the primary feeder waveguide
5 through an aperture so that received signals from N helical
6 antenna elements in each of the second feeding waveguides are
7 combined at the primary feeder waveguide.

8 Prior art systems do not provide a broadband antenna with a
9 small capture area. Moreover, the prior art typically does not
10 provide a basic structure that can perform a variety of widely
11 divergent functions to radio wave electromagnetic radiation such
12 as, for instance, communication and radar. Thus, it would be
13 desirable to provide a structure that permits complete absorption
14 of electromagnetic radiation such as radar so as to eliminate
15 reflections for stealth purposes and/or which may otherwise be
16 utilized to more completely absorb radiation to act as an
17 receiving antenna, and/or may be utilized as a broadcasting
18 antenna, and/or as a modulating system to provide the receiving
19 radar with inaccurate appearance of the return signal related to
20 speed and shape, and/or other purposes as discussed in more
21 detail hereinafter. Consequently, those skilled in the art will
22 appreciate the present invention that addresses the above and
23 other problems.

1 SUMMARY OF THE INVENTION

2 It is a general purpose and object of the present invention
3 to provide an improved air interface device for functioning with
4 electromagnetic radiation.

5 Another object is to provide an air interface system that
6 may have a wide bandwidth which is comprised of a plurality of
7 elements, each of which exhibits a small capture area.

8 Another object is to provide a system that may have improved
9 stealth characteristics.

10 Another object is to provide a system that may have an
11 improved spurious-free dynamic range (SFDR).

12 These and other objects, features, and advantages of the
13 present invention will become apparent from the drawings, the
14 descriptions given herein, and the appended claims. However, it
15 will be understood that above listed objects and advantages of
16 the invention are intended only as an aid in understanding
17 aspects of the invention, are not intended to limit the invention
18 in any way, and do not form a comprehensive list of objects,
19 features, and advantages.

20 Accordingly, an electromagnetic wave interface system is
21 provided which may comprise one or more elements such as, for
22 instance, an array of bristles forming a surface of the
23 electromagnetic wave interface system wherein each bristle is
24 comprised of conductive material. Respective termination sections

1 from a plurality of termination sections that may be electrically
2 connected to corresponding bristles of the array of bristles. In
3 one embodiment, the plurality of termination sections may
4 comprise one or more impedance elements comprising a real and
5 imaginary component. The real and imaginary component may be
6 selected to produce a desired reflected electromagnetic wave from
7 the surface. The real component may or may not be zero and/or
8 the imaginary component may or may not be zero. The real
9 component (often a resistance that absorbs electrical energy) may
10 have a negative value, i.e., the real component is an amplifier
11 (that produces electrical energy).

12 The impedance elements may comprise a time-varying phase
13 modulator to thereby modulate an impinging electromagnetic wave
14 encountering the surface so as to produce a reflected
15 electromagnetic wave from the surface that may have a different
16 frequency than the impinging electromagnetic wave to thereby
17 deceive Doppler speed measurements from an observer. Each of the
18 plurality of termination sections may also comprise one or more
19 resistance elements with a magnitude selected for absorbing
20 substantially all electromagnetic wave energy received by each
21 respective bristle of the array of bristles.

22 The system may further comprise a ground plane comprised of
23 electrically conductive material wherein the proximal end of each
24 of the array of bristles may be supported by the ground plane.

1 The system may further comprise a plurality of transmission lines
2 for electrically connecting the array of bristles to the
3 plurality of termination sections.

4 In one preferred embodiment, at least a portion of the
5 plurality of termination sections comprises an integrated
6 circuit. Each of the plurality of termination sections may also
7 comprise an analog to digital converter for selectively
8 converting electromagnetic wave energy received by each
9 respective bristle of the array of bristles.

10 In one preferred embodiment, each of the plurality of
11 termination sections may comprise one or more selecting elements
12 to select different functions of the termination sections. The
13 one or more selecting elements may be operable for selecting
14 resistive components for electrical connection with the plurality
15 of bristles, and/or for selecting the matched resistive
16 components for connection with the plurality of bristles, and/or
17 for selecting a respective transmitter for electrical connection
18 with a respective of each of the plurality of bristles, and/or
19 for selecting a respective modulator for electrical connection
20 with a respective of each of the plurality of bristles, and/or
21 for selecting the one or more reactances for electrical
22 connection with the plurality of bristles. In one embodiment,
23 the selecting elements are implemented within an integrated
24 circuit.

1 BRIEF DESCRIPTION OF THE DRAWINGS

2 A more complete understanding of the invention and many of
3 the attendant advantages thereto will be readily appreciated as
4 the same becomes better understood by reference to the following
5 detailed description when considered in conjunction with the
6 accompanying drawings, wherein like reference numerals refer to
7 like parts and wherein:

8 FIG. 1 is a cross-section taken along arrows I-I of FIG. 2,
9 of an individual interface sensor in accord with one embodiment
10 of the present invention;

11 FIG. 2 is a top plan view showing a plurality of sensors of
12 the type shown in FIG. 1 in accord with an embodiment of the
13 invention;

14 FIG. 3 is a top plan view showing an array of sensors of the
15 type shown in FIG. 1 and FIG. 2;

16 FIG. 4 is a side elevational view, partially in phantom
17 line, showing an array with sensors similar to the sensor of FIG.
18 1 with normalized relative dimensions of one embodiment of the
19 sensor(s) wherein coaxial transmission lines formed in the ground
20 plate may further selectively connect to switching elements for
21 multifunctional operation of the array in accord with one
22 possible embodiment of the invention;

23 FIG. 4A is a side elevation of a pair of adjacent sensors
24 like the one in FIG. 4, which insofar as the invention is

1 presently understood, is illustrative of relative proportions of
2 a sensor configuration for operational use;

3 FIG. 4B is a perspective view, which insofar as the
4 invention is presently understood, is illustrative of the
5 hairbrush type construction of a sensor in accord with one
6 possible embodiment of the invention;

7 FIG. 5 is a top plan view schematically showing an array of
8 interface sensors and terminations which may be monolithically
9 implemented in accord with another embodiment of the invention;
10 and

11 FIG. 6 is a side elevational view of the array shown in FIG.
12 5 in accord with the present invention.

14 DESCRIPTION OF THE PREFERRED EMBODIMENT

15 The present invention provides an electromagnetic radiation
16 interface whose basic construction may be utilized to perform
17 widely divergent functions, some of which are discussed
18 hereinafter. Technically, the present invention is not an
19 antenna in the traditional sense. An antenna in the traditional
20 sense implies a device with a single port that can be coupled to
21 a transmitter or a receiver. The present invention provides an
22 air or space interface between a wide bandwidth of
23 electromagnetic radiation and one or more processors. In one
24 embodiment, different types of processors may be selectable so

1 that the function of the interface is then also selectable. The
2 present invention may be utilized as an antenna if all energy
3 from each of the sensor elements, discussed hereinafter, is
4 coherently recombined in an electronic system coupled to the
5 elements of the surface. However, in another embodiment, the
6 present invention may be utilized as an electrically "black" air
7 or space interface surface that, with minimal loss, "guides" all
8 incident electromagnetic energy to ports where the energy could
9 either be recovered, or dissipated. If all the energy were
10 recovered, then the surface would behave as an ideal antenna. If
11 all energy were dissipated, then the interface surface would be
12 an ideal coating for an electrically stealthy object.
13 Alternative terminations may be utilized that cause the surface
14 to appear to be one object when it is another. Actively
15 modulating the terminations on the energy ports could cause a
16 fixed object to appear to be moving, or a moving object to appear
17 to be moving at a different speed.

18 Referring now to FIG. 1, there is shown one possible
19 embodiment of a single sensor element 10, shown in a side
20 elevational view that may be utilized in interface surfaces or
21 interface systems. Array 100 shown in FIG. 3, is an array of
22 sensors such as that of FIG. 1, shown looking down from the top
23 of the array. An enlarged portion of array 100 is shown in FIG.
24 2. Array 100 may sometimes in this specification or in the

1 appended claims be referred to as an "electromagnetic radiation
2 interface surface" or an "electromagnetic radiation interface
3 system." Sensor 10 is comprised of bristle 12. In this
4 example, bristle 12 is generally conically shaped to provide an
5 impedance match with the dielectric medium surrounding bristle 12
6 which, in this case, is air. However the shape of bristle 12 is
7 more generally elongate and may vary as desired. One variation is
8 shown in FIG. 4A. As another example, bristle 12 may be
9 frustoconically shaped generally as shown in FIG. 4 with a base
10 23 and an apex 25. Apex 25 which may be pointed, rounded,
11 flattened, or otherwise shaped as suitable depending on frequency
12 of operation and the like. Depending on the permittivity of air
13 or other medium, such as space, the shape of bristle 12 may be
14 varied in order to provide an impedance match therewith.

15 Bristle 12 is electrically connected to dielectrically
16 loaded coaxial transmission line 14 at inner conductor 16. For
17 practical construction concerns, coaxial transmission line 14 may
18 not be the type of co-axial transmission line which is originally
19 in the form of a cable. Especially when hundreds or thousands of
20 sensors, such as sensor 10, are utilized to form an array, as
21 suggested in FIG. 3, coaxial transmission line 14 may be more
22 conveniently formed as an integral part of the construction of
23 sensor 10. For instance, ground plane or conductive plate 18
24 may, in one embodiment, be comprised of a plate into which holes

1 28, as indicated in FIG. 1 and FIG. 2, are formed that are
2 utilized to define coaxial transmission line 14 which comprises
3 inner conductor 16, annular dielectric material 20, with an outer
4 conductor which may be comprised of the conductive surface of
5 cylinder or hole 28 in conductive plate 18. Thus, inner
6 conductor 16 and annular dielectric material 20 are disposed in
7 the space formed within cylinders or holes 28 of ground plane or
8 plate 18. Plate 18 then also serves to physically support the
9 structure of interface surface or array 100 as well as serve the
10 function of providing an effective transmission line outer
11 conductor for each sensor 10 having an outer conductor diameter
12 equal to diameter 29 (See FIG. 2 and FIG. 4) of hole 28.

13 Other embodiments, some of which are discussed hereinafter,
14 may or may not include a ground plane, or may or may not include
15 plate 18, and may or may not include dielectric material 20.
16 However, it is presently anticipated that all embodiments will
17 preferably include an array of bristles 12 mounted by some means
18 and some type of termination thereto.

19 As indicated in FIG. 1, in conjunction with FIG. 2 and FIG.
20 4, generally conic shaped bristle 12 is an electrically
21 conductive element which has a base diameter 22 (See FIG. 4) of
22 base 23, an apex diameter 24 of apex 25, and a height 26 (See
23 FIG. 1). Bristle 12 could, for instance, be comprised of metal.
24 The conical shape of bristle 12 is chosen to match the impedance

1 of the bristle 12 to an air medium for broadband frequency use.
2 To the extent that other mediums and other desired frequencies
3 are utilized, then the shape of bristle 12 may vary.

4 The term "bristle" is used because as the number of sensor
5 elements in array 100 increases, and if the overall size of array
6 100 is small, then array 100 may appear somewhat like a hair
7 brush with "bristles." As one possible example, see FIG. 4B. In
8 the embodiment of FIGS. 1 and 4, base diameter 22 (See FIG. 4) is
9 chosen so that the impedance of bristle 12 seen by coaxial
10 transmission line 14 matches the characteristic impedance of
11 coaxial transmission line 14. In the example of FIG. 1, each
12 coaxial transmission line 14 comprises inner conductor 16 and
13 annular dielectric material 20 which is disposed in cylinder or
14 hole 28. Thus, each transmission line 14 may be referred to as a
15 "follicle" that extends from and corresponds to a particular
16 bristle 12 in interface surface or array 100.

17 The characteristic impedance of coaxial transmission line 14
18 will depend on, among other factors, the diameter 29 (See FIG. 2)
19 of hole 28 for transmission line 14. In this example, diameter
20 29 of hole 28 is the effective size of an outer conductor of a
21 coaxial cable formed within conductive ground plate 18. The
22 characteristic impedance of coaxial transmission line 14 will
23 also depend on diameter 30 of inner conductor diameter 16 (See
24 FIG. 4), and the selected dielectric material 20 annularly

1 disposed around inner conductor 16 within the conductive wall of
2 cylinder or hole 28.

3 Referring to FIG. 2, the "signal capture area" of each
4 sensor 10 is referred to as a square formed by preferably equal
5 distances 32 in each of two perpendicular directions around each
6 sensor 10 so as to be uniformly distributed over the area of the
7 array. Thus, the capture area of each individual sensor 10 may in
8 this example be equal to the total area of the array divided by
9 the number of sensors 10 therein.

10 In this preferred embodiment, sensors 10 are uniformly
11 distributed over the areas of the array as indicated in FIG. 3.
12 Distance 34 is the distance from sensor center to the sensor
13 center of the adjacent sensors 10. Distance 36 is the distance
14 between cylinders or holes 28. As noted above, holes 28 may be
15 formed in conductive plate 18 such that the surface of each
16 cylinder or hole 28 thereby effectively creates the outer
17 conductor of each coaxial transmission line 14. Thus, distance 36
18 may be restated as the distance from the outer conductor of a
19 coaxial transmission line 14 for a particular sensor 10 to the
20 outer conductor of the coaxial transmission line 14 for the
21 adjacent sensors (See FIG. 2 and FIG. 4).

22 The normalized dimensions for sensor 10 are discussed
23 hereinafter to provide the relationship between the various
24 dimensions. Normalized dimensions are given because the

1 construction of sensor 10 and/or sensor array 100 may be of
2 different sizes. The different sized dimensions will affect the
3 bandwidth of interface surface or array 100.

4 However, some dimensions will affect only the upper or lower
5 bandwidth frequency. For instance, selecting an appropriate
6 value for element to element spacing 34 will clearly affect each
7 sensor 10 capture area. Since all other dimensions will scale
8 appropriately, only the upper frequency of operation will be
9 affected by a change in sensor 10 capture area due to the
10 corresponding change in frequency characteristics of coaxial
11 transmission line 14 as the dimensions thereof change.

12 For convenience, the normalized spacing is given in terms of
13 the element to element spacing 34. Therefore assuming that
14 dimension 34 is 1.0 units, then in one presently preferred
15 embodiment, dimension 24 of apex 25 may be 0.002 units, dimension
16 22 of base 23 may be 0.43 units, dimension 36 which is the
17 distance between cylinders or holes 28 is 0.10 units, dimension
18 or diameter 30 of inner conductor 16 (see FIG. 4) is 0.28 units,
19 and dimension 29 which is the diameter of cylinder or hole 28 is
20 0.90 units.

21 Dimension 36 is the distance between adjacent annular holes
22 or cylinders 28 in ground plane or conductive plate 18 that forms
23 the effective outer conductors of transmission lines 14 as
24 discussed above. Dimension 36 between holes 28 provides the

1 approximate thickness of the effective outer conductor for a
2 coaxial cable formed by making holes in conductive plate 18. In
3 one preferred embodiment of the invention, dimension 36 is
4 greater than zero to thereby utilize plate 18 for mechanical
5 stability of array 100 and to provide that the effective outer
6 conductor of the coaxial transmission lines 14 have at least some
7 metallic thickness completely surrounding dielectric material 20.

8 However, as discussed earlier, ground plane or plate 18 may
9 not be utilized in all embodiments of the invention. Thus,
10 dimension 32 may be made close to or equal to dimension 29 of hole
11 or cylinder 28 in plate 18, or 1.0 units. In another embodiment,
12 the dimension 36 may become very small so that the effective
13 thickness of the outer sheath is small but still may be utilized
14 as an outer conductor for a coaxial cable as discussed above.

15 It will be understood that the "units" referred to herein
16 are intentionally undefined and may vary depending on the desired
17 construction, bandwidth desired and so forth. The length 26 of
18 bristle 12 is left open and will depend on the particular
19 construction with the best lengths presently left to empirical
20 determination. In one embodiment, a ratio of length 26 to
21 sensor-to-sensor of 12:1 is presently believed to provide an
22 effective embodiment for construction of an array insofar as the
23 invention is presently understood (See FIG. 4A.) The longer the
24 length 26 compared to the wavelength of operations, the better.

1 Actual operational embodiment of sensors 10 may be formed with a
2 uniform diameter pedestal portion 37, as shown in FIG. 4A,
3 extending between ground plane 18 and base 23 of the conical
4 sensor section. In this embodiment, the length of pedestal
5 portion 37 is non-critical. In this example, dielectric material
6 20, which may or may not include an outer conductive sheath,
7 extends upwardly somewhat from ground plane 18.

8 In any practical embodiment, interface surface or array 100
9 of sensor elements 10 will have a finite physical extent and the
10 spacing of each sensor 10 from the neighbors thereof will have
11 some practical minimum value. The lower frequency bound at
12 which the interface surface or array 100 will exhibit good
13 absorption will be determined by the finite physical extent of
14 the array and may, depending on construction, be related to the
15 wavelength or half wavelength of the lowest frequency to be
16 captured. The upper frequency bound will depend on the spacing
17 between individual sensor elements 10 and/or the upper frequency
18 limits of coaxial transmission line 14.

19 For example, which may vary considerably depending on
20 construction, a one square meter array may have a bandwidth with
21 a lower frequency of 300 MHz. If the upper frequency cut off is
22 determined by coaxial cable having an upper frequency of 25 GHz,
23 then it will be appreciated that the bandwidth is very wide.
24 Moreover, a much smaller array with 0.1 square meter dimensions

1 might then have a bandwidth with a lower frequency of very
2 roughly 3GHz with the upper frequency still at 25 GHz assuming
3 the coaxial cable dimensions are not made smaller. Based on
4 these very rough approximations, this would also result in a very
5 wide bandwidth antenna having a relatively small capture area.
6 It will be understood that the upper frequency cut off of coaxial
7 transmission line 14 can be much higher and may be quite high
8 depending on the dimensions thereof. If the coaxial transmission
9 line 14 is operated as a TEM transmission line, e.g., a commonly
10 used mode of operation wherein the electric and magnetic field
11 vectors are both normal to the direction of propagation, then
12 there is no lower cutoff frequency produced as a result of
13 coaxial transmission line 14.

14 The characteristic impedance of the TEM mode of propagation
15 in coaxial transmission line 14 is a real resistance, e.g., 50
16 Ohms. When a coaxial transmission line with characteristic
17 impedance Z_0 is terminated by a resistive element such as element
18 38 with an impedance of Z_0 , then transmission line 14 is said to
19 be matched. No electromagnetic energy is reflected from the
20 matching termination. In other words, all electromagnetic energy
21 propagating in transmission line 14 is absorbed by element 38.
22 Thus, if each TEM transmission line 14 (follicle) in array 100
23 supporting a bristle 12 on interface surface or array 100 is
24 terminated in a resistive element that matches the TEM

1 transmission line 14 characteristic impedance, then all
2 electromagnetic energy incident on interface surface or array 100
3 will be absorbed by the corresponding resistive element, e.g.,
4 element 38. In this case, interface surface or array 100 will
5 appear electrically "black" to an observer who has transmitted an
6 electromagnetic wave or pulse and is looking for a return signal.

7 As noted above, prior art broadband receiving systems are
8 performance limited by the inability to realize sufficient
9 spurious-free dynamic range in the analog portions of the
10 receiving system. Digital signal processing (DSP) radio systems,
11 on the other hand, have much greater spurious free dynamic range
12 (SFDR) because the SFDR increases about 5 dB for each mantissa
13 bit. For instance, software defined radio may utilize a radio
14 receiver and/or a transmitter, where the received signal is
15 digitized and then processed using software-programmable digital
16 signal processing techniques. Digitization may occur at the RF,
17 IF, or base band. Thus, a typical DSP system using 24 bit
18 arithmetic could exhibit 120 dB SFDR, which is much higher than
19 prior art broadband systems.

20 In the disclosed system, each bristle 12 collects
21 electromagnetic energy from a small, scaleable, capture area.
22 The total capture area of interface or array 100 is the sum over
23 all bristles 12. If the signal from each bristle 12 is first
24 converted to a digital form by a plurality of A/D converters, and

1 all signals are combined in the digital domain, then there will
2 be an improvement in SFDR for the combined receiver system.
3 Thus, an A/D converter 40 (FIG. 1) may be utilized with each
4 bristle 12 and transmission line 14 to sample the electromagnetic
5 potential relative to a common plane such as ground plane 18 and
6 periodically convert the magnitude of the electromagnetic
7 potential to a digital word. To a first approximation, the
8 improvement is proportional to the ratio of the capture area of a
9 single bristle 12 to the capture area of all bristles combined in
10 interface surface or array 100. Thus, if interface surface or
11 array 100 has 1000 bristles, then interface surface or array 100
12 would have 30 dB more SFDR than an antenna with the same capture
13 area, other technologies being equal.

14 Commonly assigned U.S. Patent 6,466,167 entitled "Antenna
15 Systems and Method for Operating Same" is illustrative of a
16 system which first converts the signal from each bristle to a
17 digital form and then performs processing, including sampling
18 thereon. It is of particular utility with electromagnetic radial
19 air-interface systems in accordance with the present invention,
20 and is hereby incorporated herein by reference in its entirety.

21 Further, using monolithic technologies, as discussed
22 subsequently in connection with FIG. 5 and FIG. 6, an interface
23 system with 1000 bristles may be easier and cheaper to fabricate
24 and deploy. The digital words describing the electromagnetic

1 potentials of large numbers of sensors 10 may be combined to
2 produce a digital replica of the incident electromagnetic energy
3 arriving at interface surface or array 100. This digital replica
4 of the incident electromagnetic energy field may be further
5 processed to simultaneously recover a plurality of signals
6 arriving at interface surface or array 100. One or more
7 frequencies from one or more directions of arrival may
8 characterize each signal.

9 A dual system may be used to independently excite each
10 sensor 10 in one or more interface surfaces or arrays 100 such
11 that the coordinated excitation potentials launch an
12 electromagnetic energy field carrying a plurality of signals
13 wherein each signal may be characterized by one or more
14 frequencies and one or more directions of propagation.

15 In another embodiment of the invention, a means is provided
16 for creating an active surface capable of creating a deceptive
17 electrical appearance by means of programmable electronic
18 modules. Referring to FIG. 4, switching means 42 may or may not
19 be utilized, as desired, to switch between electronic modules 44,
20 45, 46, 47, and 48, for each bristle 12. In another embodiment,
21 a single type of electronic module may be utilized for
22 terminating transmission line 14 to provide a dedicated function
23 interface surface or array 100. While a mechanical type switch
24 is shown in FIG. 4, a more practical embodiment may utilize

1 electronic switches, such as FET switches, which may be easily
2 implemented in monolithic integrated circuit construction.

3 Alternately the modules may comprise means for varying
4 impedances including variable reactances or variable resistances.

5 Note that resistance module 48 may be connected across center
6 conductors 16 of each adjacent transmission line 14 rather than
7 between center conductor 16 and ground plane 18 as discussed

8 earlier. In this case, $2Z_0$ rather than Z_0 results in impedance

9 matching for each transmission line 14. However, the impedance

10 as seen by the transmission line is still Z_0 and therefore the

11 connection across two transmission lines 14 is equivalent to

12 connecting each impedance between transmission line center

13 conductor 16 and ground plane 18 as shown in FIG. 1. Thus, with

14 switch 42 connected to module 48, all incident electromagnetic

15 energy will be absorbed by resistive elements of module 48 and

16 interface surface or array 100 will appear electrically "black"

17 as discussed herein. Note that another module, such as module

18 47, could comprise a resistance with a negative magnitude whereby

19 the reflected signal will be amplified by a factor relating to

20 the real magnitude. In other words a reflection coefficient has

21 both a real and an imaginary part. The real part may be used to

22 control the amplitude of the reflected wave. If the real part is

23 positive, then a reflected signal will be attenuated by a factor

24 related to the real magnitude. If the real part is negative, as

1 discussed above, then the reflected signal will be amplified by a
2 factor related to the real magnitude.

3 If the energy ports at the end of each transmission line 14
4 are terminated by a means that reflects energy, e.g., a reactive
5 termination which might comprise termination module 46, then the
6 surface will appear as a reflecting surface to incident
7 electromagnetic radiation. Variations in the reactance magnitude
8 and sign will determine the phase of the reflected signal. If
9 switch 42 switches between characteristic impedance of 48 and
10 reflective termination module 46, then interface surface or array
11 100 can appear to change electrical characteristics completely
12 with respect to an observer who has launched an electromagnetic
13 wave. Thus, if variable controls such as switch 42 or if, for
14 instance, module 45 comprises other variable means for the real
15 and imaginary aspects of the reactance, then the reflected signal
16 will also be correspondingly varied. If the end of each
17 transmission line 14 is terminated by means that is altered in
18 phase and/or amplitude, then the reflected wave could appear to
19 an observer to be caused by a different object. If the energy is
20 modulated, such as by a biphase modulator, or any other suitable
21 time-varying phase modulator in module 44, then the modulation
22 can be made to appear on the reflected wave. If the observer is
23 measuring Doppler effects (the difference in frequency between
24 incident and reflected signals) to thereby determine the speed of

1 interface surface or array 100, then the so modulated wave could
2 cause a fixed-location surface to appear to be moving at a rate
3 of speed determined by the modulation frequency and/or a moving
4 surface to appear to be moving at a faster or slower speed. If
5 frequency selective filters are added to the ends of transmission
6 lines 14, then the reflected energy would have a tailored
7 frequency dependent appearance. In another embodiment, some
8 transmission lines 14 could be terminated in one way, and others
9 terminated in another way to produce a return signature that
10 deceives the observer. In another embodiment, each termination
11 module may comprise a transmitter such that an electromagnetic
12 wave is produced by a combination of the transmitters
13 transmitting through the array of bristles 12. The transmitters
14 may be either analog or digital transmitters. Thus, the
15 disclosed novel interface surface or array 100 may offer a wide
16 variety of functions acting on electromagnetic waves that may be
17 deployed dynamically by means of programmable and/or switchable
18 electronic circuits, such as circuits 44, 45, 46, 47, 48, and/or
19 other circuits, that terminate transmission lines 14.

20 FIG. 5 and FIG. 6 show interface surface or array 100 which
21 may be implemented monolithically. Each bristle 12 is terminated
22 in a module 50. Module 50 is an integrated circuit that may or
23 may not include FET switches to switch between various
24 termination packages, such as any of the termination packages

1 described above. For instance as discussed above, termination
2 packages may be designed for absorbing electromagnetic energy
3 completely for stealth (termination of transmission lines at
4 their characteristic impedance, recovering all energy as a
5 perfect antenna (digital receivers connected to all transmission
6 lines), reflecting energy with tailored frequency dependent
7 appearance (frequency selective filters connected to all or
8 selected transmission lines), reflecting modulated energy
9 (biphase modulators connected to all transmission lines), and/or
10 sending signals (transmitters connected to each transmission
11 line). Various other means may be provided for interconnecting
12 the modules, e.g., resistance modules are connected across and
13 between sensors of each adjacent set of sensors and/or between
14 each sensor and the surrounding conductor.

15 FIG. 6 shows a side view. Each package 50 may be
16 implemented within a larger integrated circuit substrate or layer
17 52. Different means for connecting bristles 12 to packages 50
18 may be utilized. For instance, each bristle 12 may plug into a
19 metallic socket 54 that is etched from an upper metallic layer as
20 part of the integrated circuit package. Depending on the
21 frequencies involved, layer 56 may or may not be a ground plane
22 with cylinders 58 filled with dielectric material. For instance,
23 layer 56 may simply be a layer of dielectric material with
24 bristles 12 also comprising the inner conductor of the

1 transmission line. As another alternative, depending on the
2 frequencies, wherein the diameter of the transmission line will
3 decrease in order to accommodate higher frequencies, array 100
4 may not include either the ground plane or dielectric material
5 but instead rely on the shape and size of bristle 12 to provide
6 all impedance matching with respect to the medium and packages
7 50. Moreover, the impedances produced in packages 50 may be
8 varied and/or variable to provide impedance matching with respect
9 to bristle 12.

10 Interface means or processors 60 may be utilized to
11 communicate with packages 50 to coordinate data flow and control
12 the activities thereof through control/data lines 62 and 64.
13 Thus, it will be appreciated that the concepts discussed in
14 connection with interface surface or array 100, whereby the
15 surface can act in many different modes depending on the
16 termination packages, can be implemented in different ways with
17 some presently preferred embodiments being disclosed herein.

18 While the invention has been described in relation to
19 employing the hereinabove disclosed principles of operation to a
20 square polygon form of tessellation of an array, it is to be
21 understood that they may be applied to other forms of tessellation
22 as well. Further, while described relative to sensor 10
23 projecting normal to a flat supporting surface, the principles
24 may be also applied to sensor projecting from other shaped

1 surfaces such as a cylindrical, spherical, conical, elliptical,
2 hemispherical, or any other desired shape. While one preferred
3 embodiment utilizes coaxial transmission line 14 for connecting
4 each bristle 12 to a desired termination, other types of
5 transmission lines including strip lines, micro strips, or other
6 suitable means for transmitting energy at radio wave frequencies
7 may be utilized.

8 Many additional changes in the details, materials, steps and
9 arrangement of parts, herein described and illustrated to explain
10 the nature of the invention, may be made by those skilled in the
11 art within the principle and scope of the invention. It is
12 therefore understood that within the scope of the appended
13 claims, the invention may be practiced otherwise than as
14 specifically described.

2

3

MULTI-PURPOSE ELECTROMAGNETIC RADIATION

4

INTERFACE SYSTEM AND METHOD

5

6

ABSTRACT OF THE DISCLOSURE

7

An electromagnetic radiation interface is provided that is

8

suitable for use with radio wave frequencies. A surface is

9

provided with a plurality of electrically conductive bristles. A

10

corresponding plurality of termination sections are provided so

11

that each bristle is terminated with a termination section. The

12

termination section may comprise one or more different

13

termination packages for operating on received electromagnetic

14

radiation and/or producing desired reflections and transmissions.

15

In one embodiment, switches and termination packages may be

16

implemented within integrated circuits wherein the switches may

17

be utilized to switch between different termination packages.

18

The termination packages may include selected fixed reactances

19

and/or modulators designed to produce desired reflections, e.g.,

20

Doppler effects to make it appear the surface of the interface is

21

moving a speed different than the actual speed.

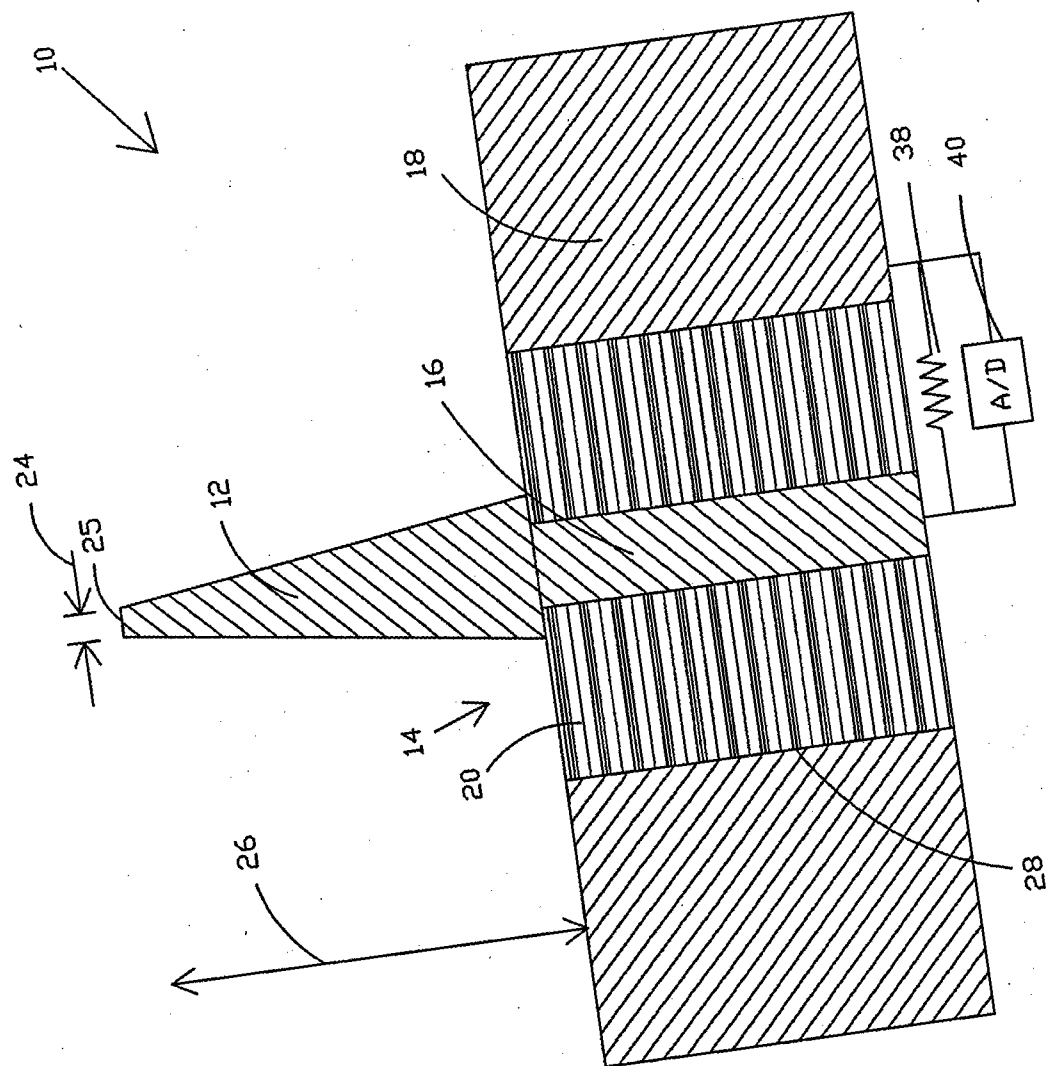


FIG. 1

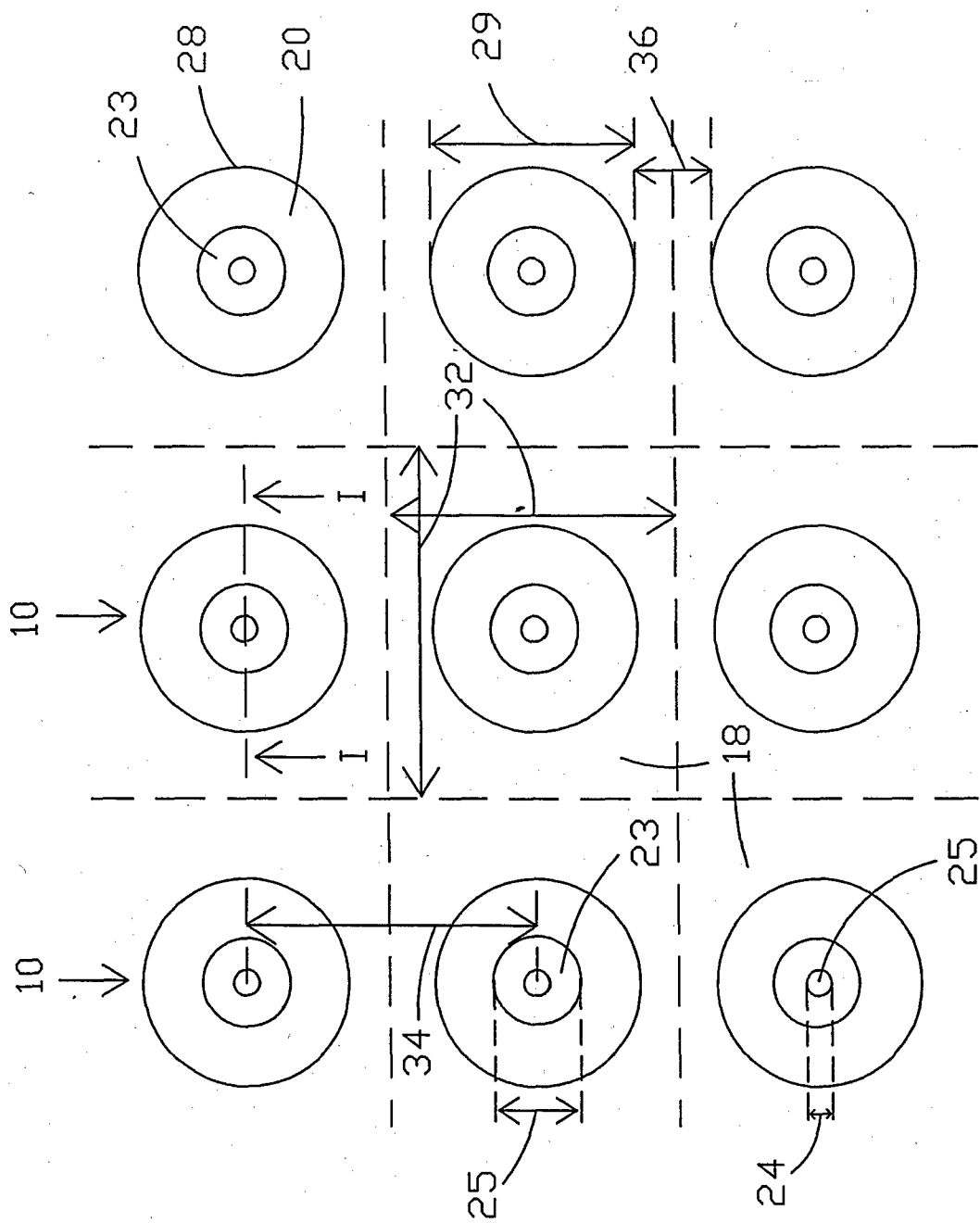


FIG. 2

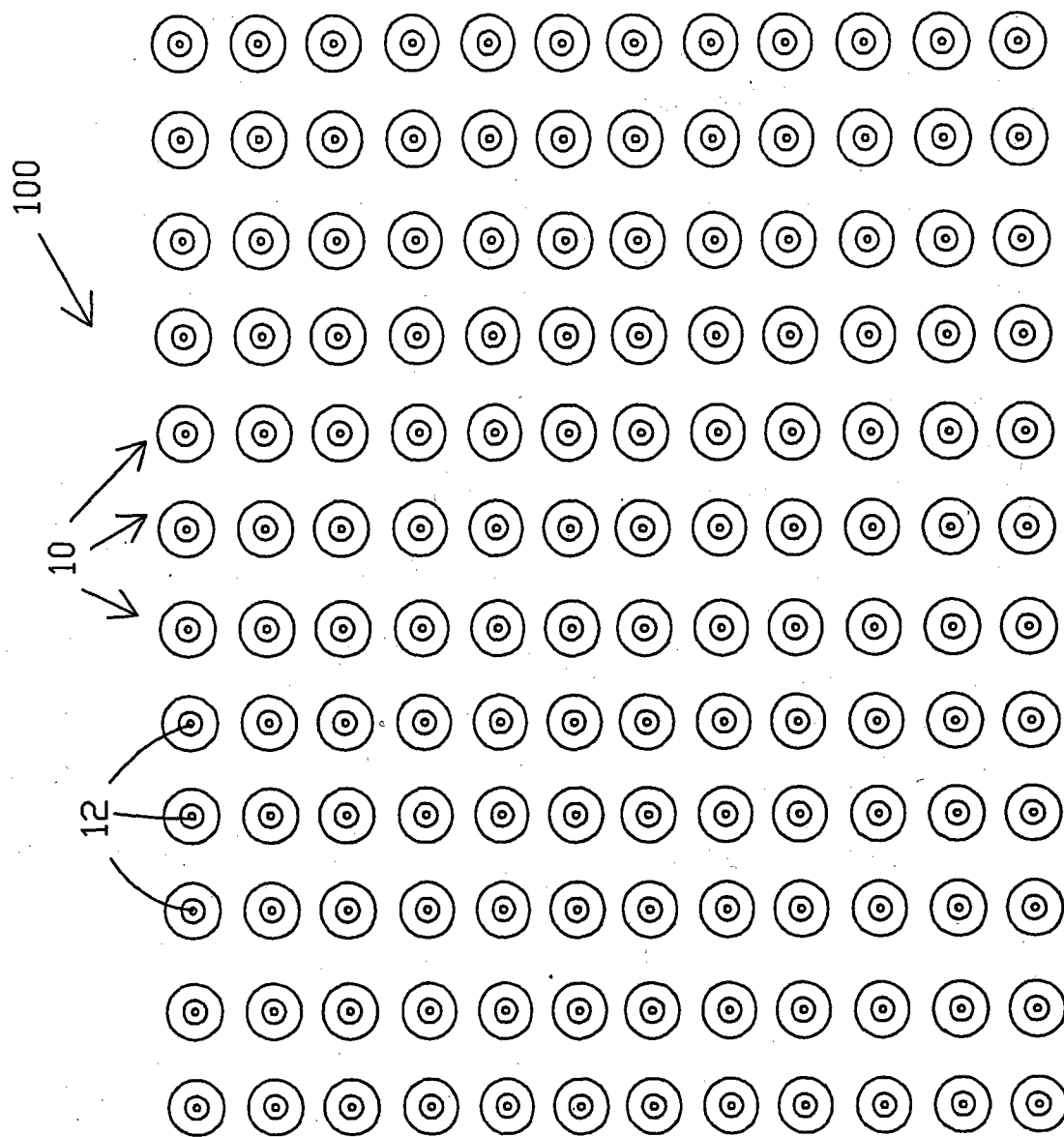


FIG. 3

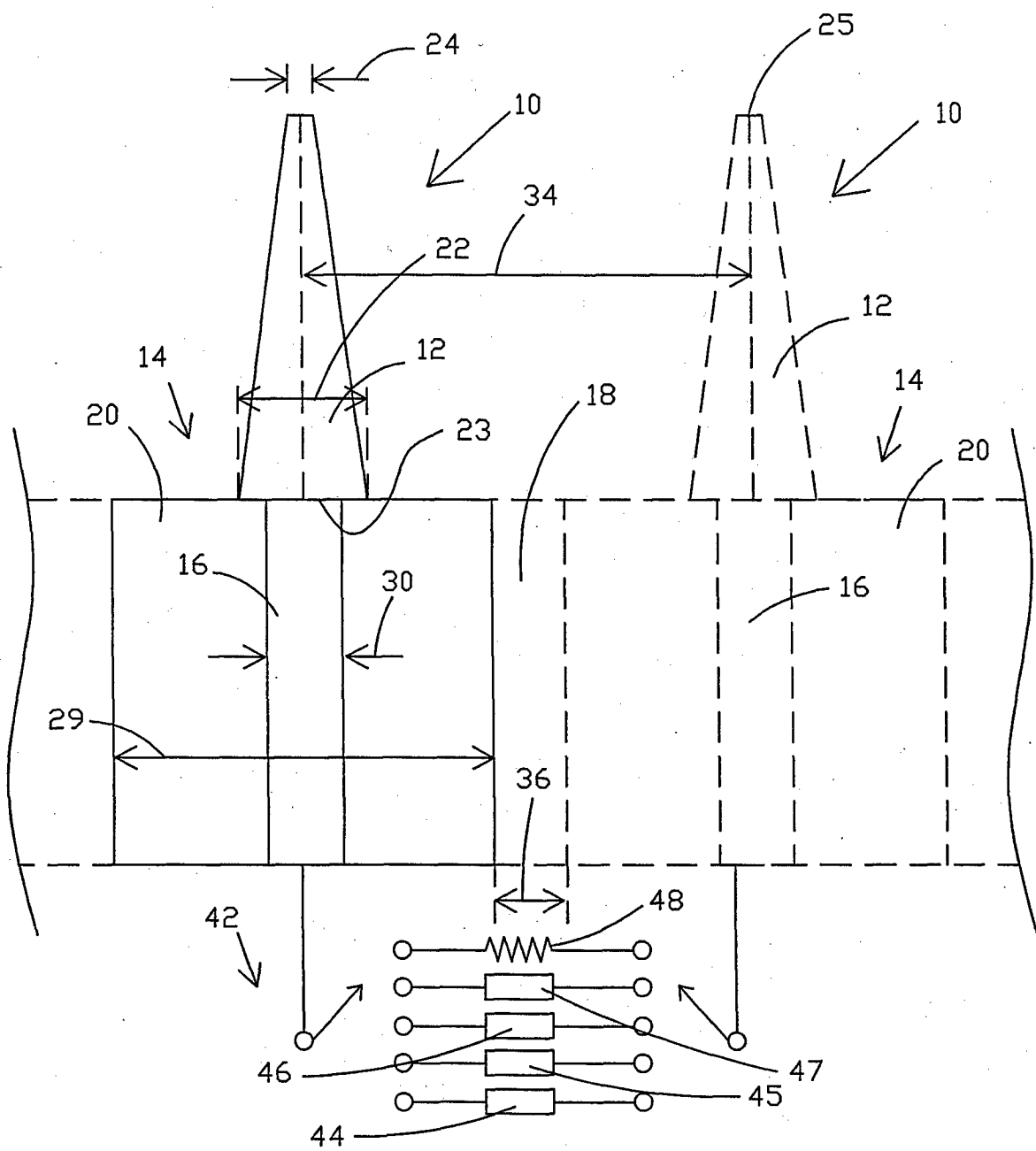


FIG. 4

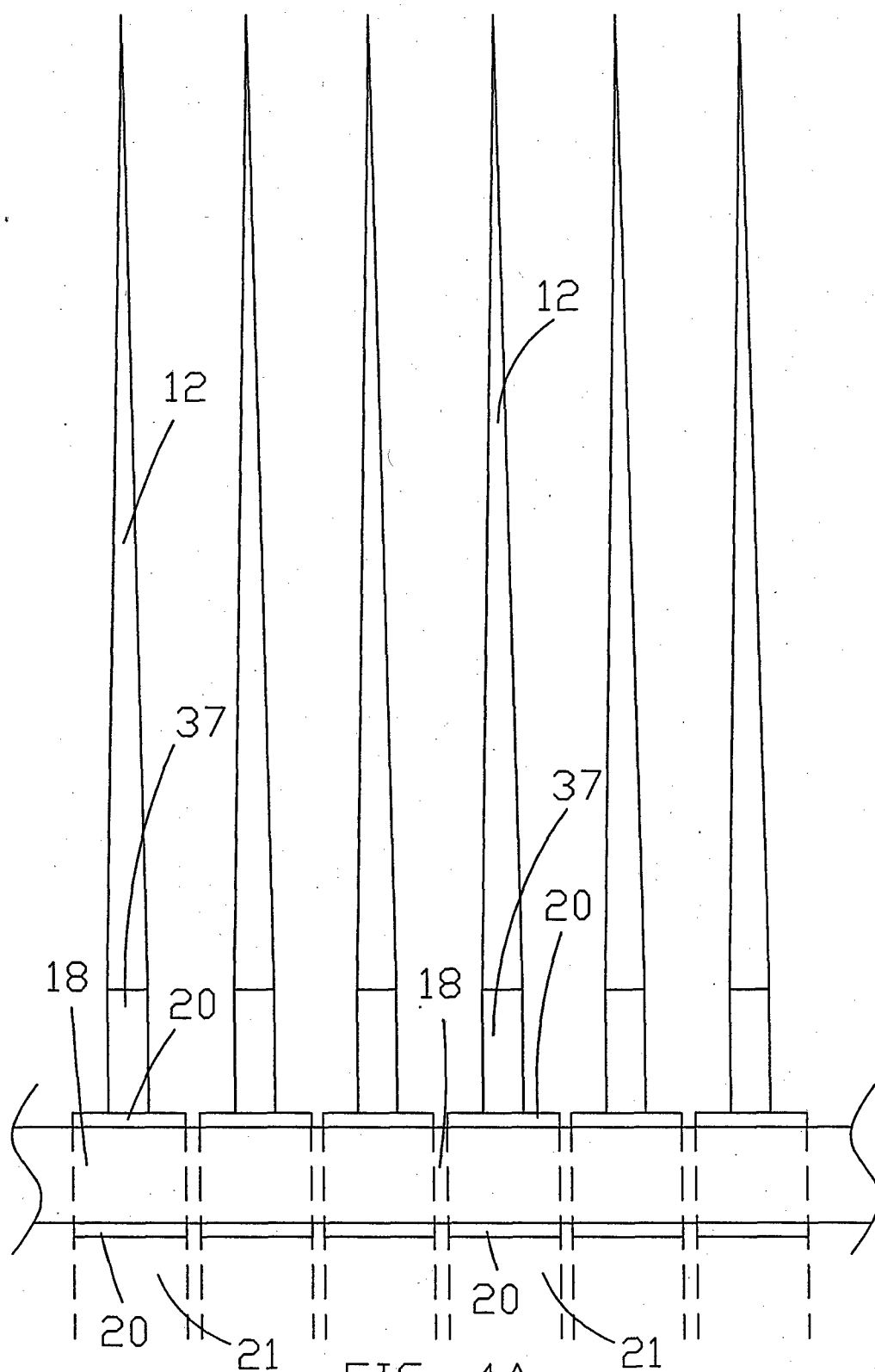


FIG. 4A

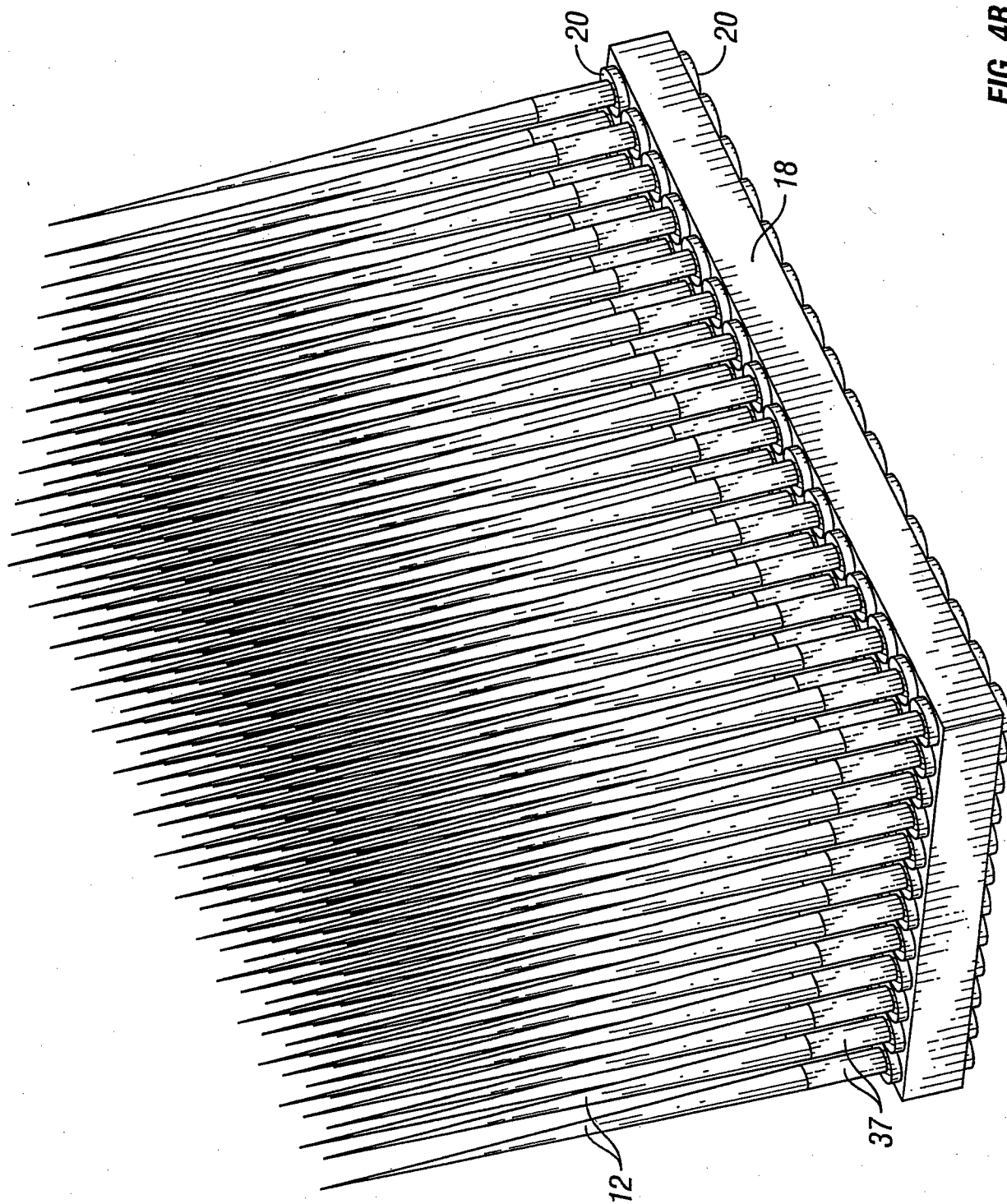


FIG. 4B

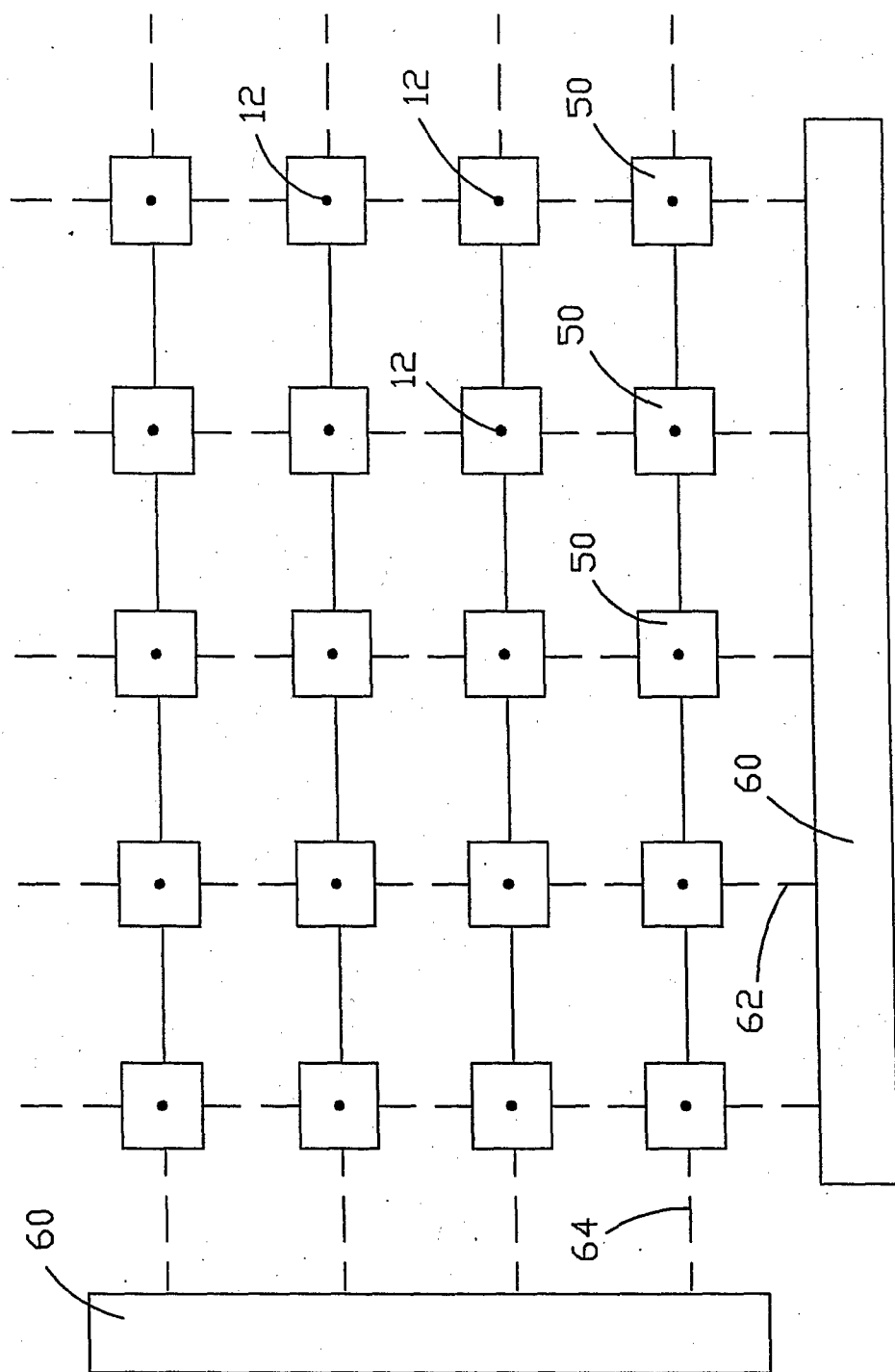


FIG. 5

100

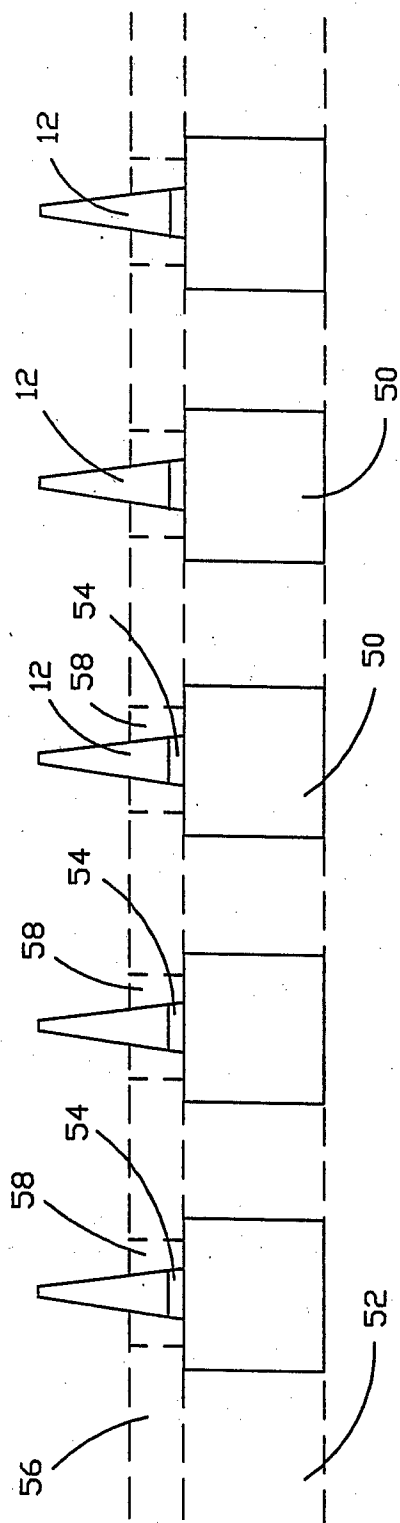


FIG. 6